WATER LEVEL AND VEGETATION CHANGE ANALYSIS AT STILLWATER WILDLIFE REFUGE

by

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INTRODUCTION

Changes in landscape and land cover be can be attributed to natural or human induced forces. Natural change might be caused by simple passing of the seasons, climatic fluctuations or natural disaster such as flooding. Human induced change is caused by a multitude of activities such as urban or agricultural development, wetland drainage or water diversion. The contributions of man and nature can be difficult to separate.

Digital analysis of Landsat thematic mapper (TM) data is one tool which can be used to detect and quantify land cover change. Very wide areas can be observed with relatively high resolution at far less expense than land surveying or aerial photography. The major problem associated with the use of remote sensing imagery for change detection is the availability of high quality images within the required temporal and spatial constraints of the project. Historical TM data is only as old as 1982 and other Landsat imagery dates to 1972 with the launch of Landsat 1 (Sabins, 1987). There is some question about the future of the Landsat program but the overwhelming support of the scientific community and the greatly expanding interest in global change analysis should ensure its survival and increased virility.

The aim of this project is to determine the feasibility of detecting change in surface water levels and associated wetland biomass at the Stillwater Wildlife Refuge in western Nevada. This wetland area has experienced considerable natural and man-caused change in recent times and is today shrinking to near critical size.

BACKGROUND

In prehistoric times the Stillwater area and most of the valleys of western Nevada were covered by Lake Lahonton, a great inland sea. Ancient shorelines of Lake Lahonton are visible in the Stillwater Mountains adjacent to the wetlands. As Nevada's climate became more arid the lake dried up and wetlands formed at the terminus of the Carson River, flowing from the Sierra Nevada Range.

Around the turn of the century farming became more important in the Lahonton Valley around Fallon with the completion the U.S. Bureau of Reclamation Newlands Project in 1902. This was the Bureau's first effort at making the desert bloom. This project diverted essentially all the flow of the lower Carson River and imported a large portion of the Truckee River flow (which would naturally flow to Pyramid Lake) for irrigation in the Fallon Area. Agricultural drainage water flows to the wetlands through 350 miles of canals after irrigating some 67 000 acres of Newlands Project lands (Vetter, 1989). As the wetlands diminished with increased water demand, concern grew and the Fallon National Wildlife Refuge was established in 1931. In 1948 224 000 acres of the Newlands Project lands were designated as the Stillwater Wildlife Management Area. Wetland development and restoration soon produced about 34 000 acres of wetland habitat (Department of Wildlife, State of Nevada, 1982). Unfortunately no water rights were established for the wetlands when the land was reserved. Increased water demand by the Fallon farmers, the cities of Reno/Sparks, and the endangered cui-ui fish of Pyramid Lake in combination with three straight years of drought have reduced the wetlands to approximately 4000 acres. (Thompson, 1989).

The Stillwater Wildlife Management Area is an important link in the Pacific Flyway used by migratory birds and is also an important breeding ground for many bird species. Hundreds of thousands of shorebirds, ducks, and other wetland birds stop over or make their home at Stillwater (Department of Wildlife, state of Nevada, 1982). The Lahonton Valley wetlands (including Stillwater) have recently been designated a part of the Western Hemisphere Shorebird Reserve Network.

This important wetland habitat is the product of shallow water and associated submersed and emersed vegetation. Mid-latitude marshes, such as Stillwater, are renowned for their rich productivity in terms of biomass and species diversity (Weller, 1981). In arid Nevada the richness and diversity of bird, fish, insect, and vegetation species provided by wetlands is all the more striking and important.

METHODOLOGY

Landsat TM images for the dates July 7, 1984 and October 27, 1984 were acquired from the University of Nevada, Reno, Department of Geology. Image processing was carried out with Microimage Software at a Terra-Mar workstation provided by the Desert Research Institute of Reno, Nevada. Nevada experienced unusually high precipitation during the winter of 1983/84 and this is reflected in high water levels at the Stillwater wetlands. A map showing the Stillwater Wildlife Management Area is presented in Figure 1. The area covered by the TM images is boxed in red.

The July and October images were transferred from tape to the hard disk of the Terra-Mar workstation and compressed quarter scene images were registered. Twelve ground control points were chosen throughout the area surrounding the Stillwater wetlands and a 512 by 400 pixel window was extracted from the scene. The July 7, 1984 and October 27, 1984 registered images are presented in Figures 2 and 3 respectively. These images are composites of TM bands 1, 4, and 5 with

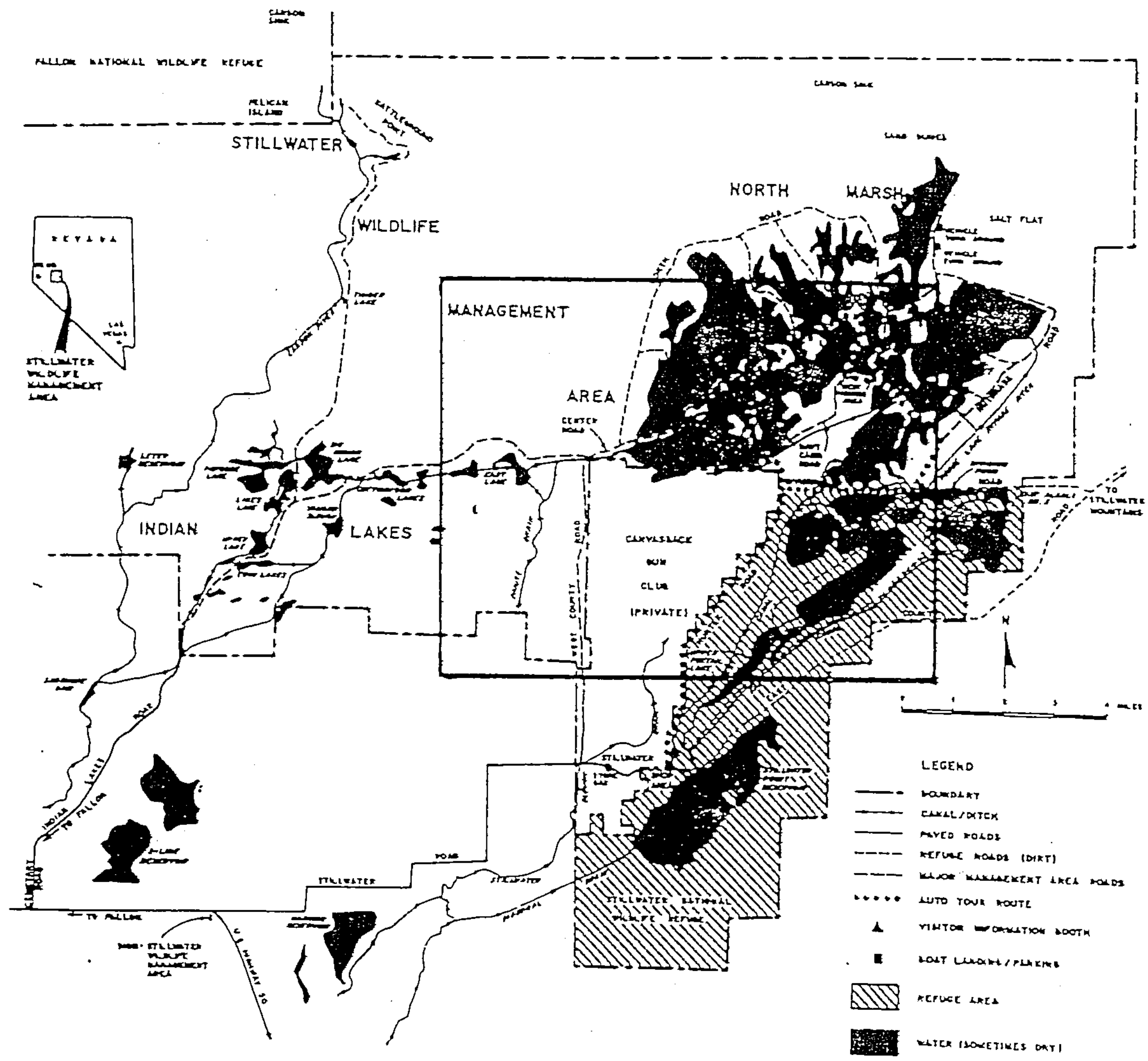

Figure 1: Map of Stillwater Wildlife Management Area with TM image area marked in red (after Department Of Wildlife, State of Nevada, 1982).

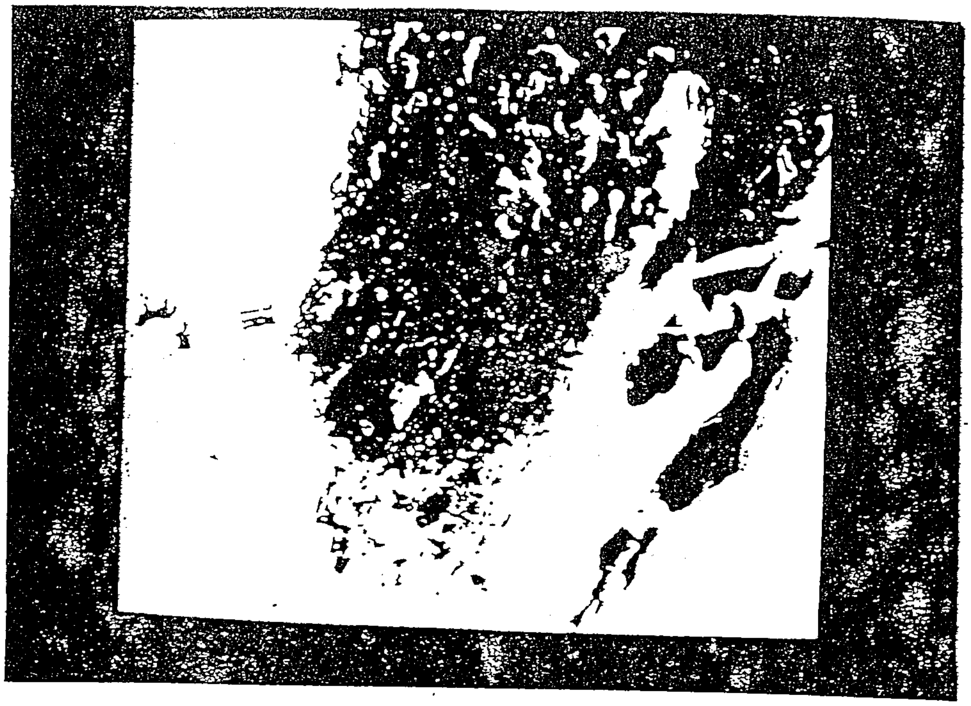

Figure 2: Stillwater wetlands composite image of TM bands 1,4, and 5 from July 7, 1984.

Figure 3: Stillwater wetlands composite image of TM bands 1,4, and 5 from October 27, 1984.

a combination of 50 percent histogram and 50 percent linear stretch and medium edge enhancement.

Surface water level change analysis between the two images was performed with a supervised classification technique. A single classification for water on both images was followed by a subtraction of the two classified images to observe change. Water appears as blue or black in the images of Figures 2 and 3. A training set or polygon was established in large blue and black areas of the July image. Care was taken to ensure that no non-water pixels were included in the polygon when overlain on both the July and October images. Pixel size for TM images was approximated at 28.5 meters square. A supervised parallelepiped classification with 5 standard deviations for parallelepiped sizing was applied to both images using the same polygon training set. Five standard deviations for parallelepiped sizing were required to ensure adequate coverage of all water surfaces. The classified images for July and October are presented in Figures 4 and 5, respectively. Water appears orange in both images. The July image was covered by 27.3 percent water or 11 228.0 acres and the October image was covered with 34.2 percent water or 14 058.6 acres. The two classified images were subtracted one from another to obtain a difference image representing the change in water levels. This difference image is presented in Figure 6. The blue color represents water that was present in October but not in July and the yellow color apparently shows water that was present in July but not October. There are very few yellow pixels and this may indicate an artifact from the registration process rather than actual water level change.

A combination of band ratioing and image subtraction was used to analyze biomass change between the July and October Stillwater images. Ratio images of TM band 4 divided by band 3 were produced for both July and October with the

Figure 4: Stillwater wetlands classified image of surface water from July 7, 1984.

Figure 5: Stillwater wetlands classified image of surface water from October 27, 1984.

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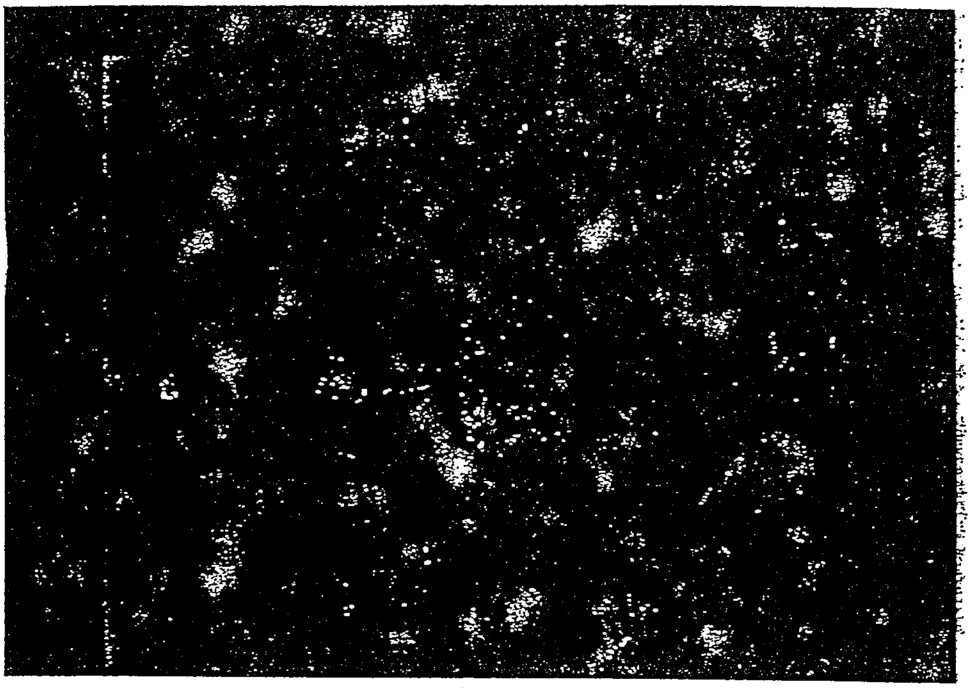

Figure 6: Stillwater wetlands difference image showing changes in surface water levels from July 7, 1984 to October 27, 1984. Blue represents positive change and yellow represents negative change.

linear decompression method. This ratio was chosen to emphasize the vegetation signal. The output images were scaled with three standard deviations. Both images were enhanced with an exponential stretch and density slicing to highlight the contrasts and are presented in Figures 7 and 8, respectively. The two unenhanced ratio images were subtracted (July from October) to produce a difference image showing vegetation change. The difference image was also exponentially stretched and density sliced and is presented in Figure 9. In this image the yellow/orange color represents vegetation that was present in July but not in October and the dark blue color represents vegetation that was present in October and not in July. Light blue/green color represents no significant vegetation change.

DISCUSSION

At the outset of this study it was anticipated that water levels at the Stillwater wetlands would be higher in July than in October because of decreasing runoff and high evaporation during the typical hot dry Nevada summer. In reality the October image was covered with 34.2 percent water and the July image, only 27.3 percent water. There are probably several reasons for the 6.9 percent increased water in October. After Spring runoff when surplus water may end up at Stillwater, the wetland water supply is controlled entirely by man. Irrigation schedules determine when and how much water ends up draining off to the wetlands. The likely explanation for increased water levels in the Fall is that irrigation drainage water, with an ample summer water supply, has simply ponded in the wetlands. Other reasons might include a decrease in evapotranspiration during the cooler Fall months and subsequent increase in water, a simple decrease in solar evaporation, or some early winter precipitation events. Looking at the water level difference image of Figure 6 the additional October water is spread fairly

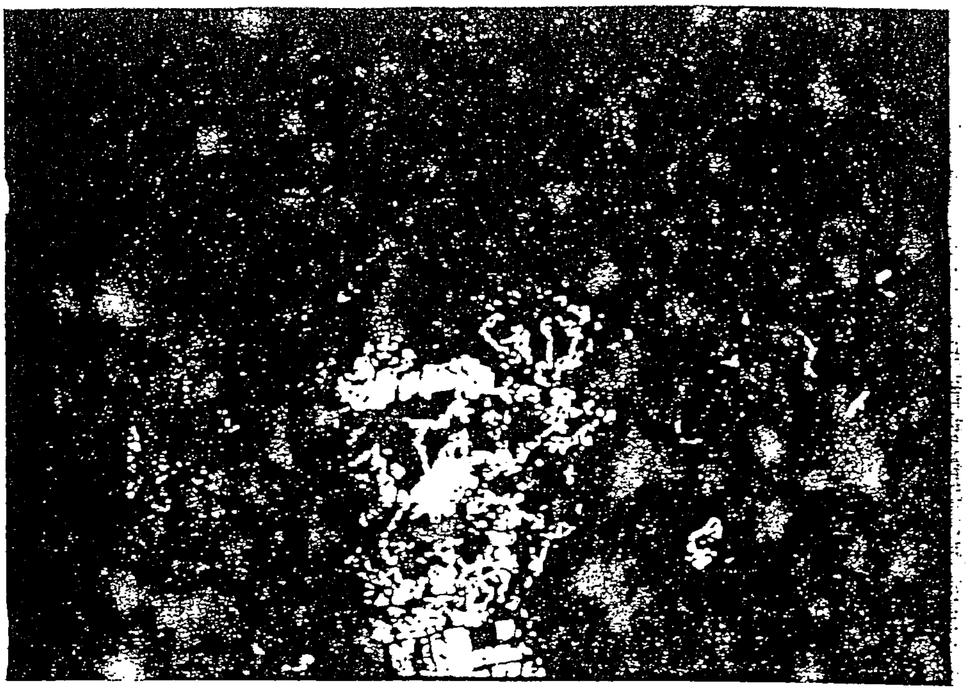

Figure 7: Stillwater wetlands band ratio image of TM band 4 divided by band 3 for July 7, 1984. Yellow/orange represents vegetation.

Figure 8: Stillwater wetlands band ratio image of TM band 4 divided by band 3 for October 27, 1984. Yellow/orange represents vegetation.

Figure 9: Stillwater wetlands July minus October difference image of the two 4/3 band ratio images. Yellow/orange represents decreased vegetation in October and dark blue represents increased vegetation in October.

uniformly throughout the wetland but there is a slightly greater increase in the southern portion of the image. In this area there are several entirely new small ponds. The increased water in the south tends to support the theory of increasing ponded irrigation runoff since the Newlands Project lands lie to the south and west of the wetlands. The water level in the Stillwater Point Reservoir and other lakes in the southeast corner of the image have increased only slightly. This may be because it is a more controlled reservoir system and not subject to uncontrolled drainage.

It was anticipated that there would be more wetland vegetation in July than October due to seasonal change and this was the case. Emersed vegetation one is likely to encounter in Nevada wetlands includes bulrush, cat-tail, and spikerush. Sago pondweed is a common species of submersed vegetation (Tueller, 1975). In the July image of Figure 2 there is a green tinge of submersed vegetation in several of the large lakes on the east side of the wetlands that is probably sago pondweed. This is also visible to some extent in Figure 7. There is also significant vegetation in the west side of the image, just south of two small ponds. The greatest portion of the vegetation lies in the center of the image in the main body of the wetlands and in the irrigated croplands to the south. There is little or no vegetation in both flooded and dry lands to the north. In the October image the submerged vegetation of the eastern lakes has virtually disappeared. Other areas of vegetation show a general decline in vigor or biomass with the exception of the southern croplands. In the difference image of Figure 9 the yellow/orange represents vegetation that was lost by October and the dark blue represents vegetation that was gained by October. Blue/green represents no change in vegetation. The submersed vegetation of the eastern lakes shows a strong yellow /orange signal. Most of the other vegetation loss has occurred in the emersed vegetation of the main wetlands. Several of the bright orange areas of vegetation loss in the southern portion of the image appear to be low areas flooded by drainage water in the Fall. Vegetation gains or dark blue areas are fairly small. The most significant of these are in the croplands of the south and may represent a late crop of alfalfa. Other increases in vegetation around the banks of the eastern lakes and the main wetlands are probably associated with the increasing water levels in October.

On April 16, 1989 the Stillwater wetlands were observed in the field. This date was possibly too early in the season to see much green vegetation. Wet areas were observed to be the exception rather than the rule and green vegetation was scarce. The only new vegetation was salt ceder along canals and banks and rare emersed bulrush and cat-tail next to water. There were large areas of dead vegetation and barren mudflats. Where there was water many wetland birds were also seen. The overall impression was one of a wetlands starved for water.

CONCLUSION

This study sought to assess the potential for using TM imagery for detecting change in water levels and biomass at the Stillwater wetlands. It was shown that water level change can be quantitatively determined with great accuracy. Changes in biomass are more gradational than water level change but qualitative and spatial change can easily be shown. This study observed change over approximately four months or the changes from Summer to Fall. A more interesting approach would be to observe long term change over many years. Anniversary date images from July or August, when vegetation is at it's peak, would probably serve best for this purpose. Remote sensing using TM or other Landsat imagery is a valuable, low cost, and efficient tool for scientists and land managers to detect and analyze changes in wetland water level and biomass.

ACKNOWLEDGMENTS

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